

Life Cycle Assessment of Atmospheric Water  
Generation Technologies and Alternative Potable  
Water Emergency Response Options

**Citizen Name / Ex. 6**



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# Study Scope

- Atmospheric Water Generator in 3 scales (large scale, medium scale and home/office scale)
  - WaterGen
  - Ecoloblue
- Bottled Water
  - Single use 16.9 oz bottles in a 24 pack
  - Multi-use 5 gallon jug
- Functional unit (i.e., basis of results) is modeled as 1 Liter of water
  - Bottle results estimate specific formats, but should not be considered representative of a specific brand

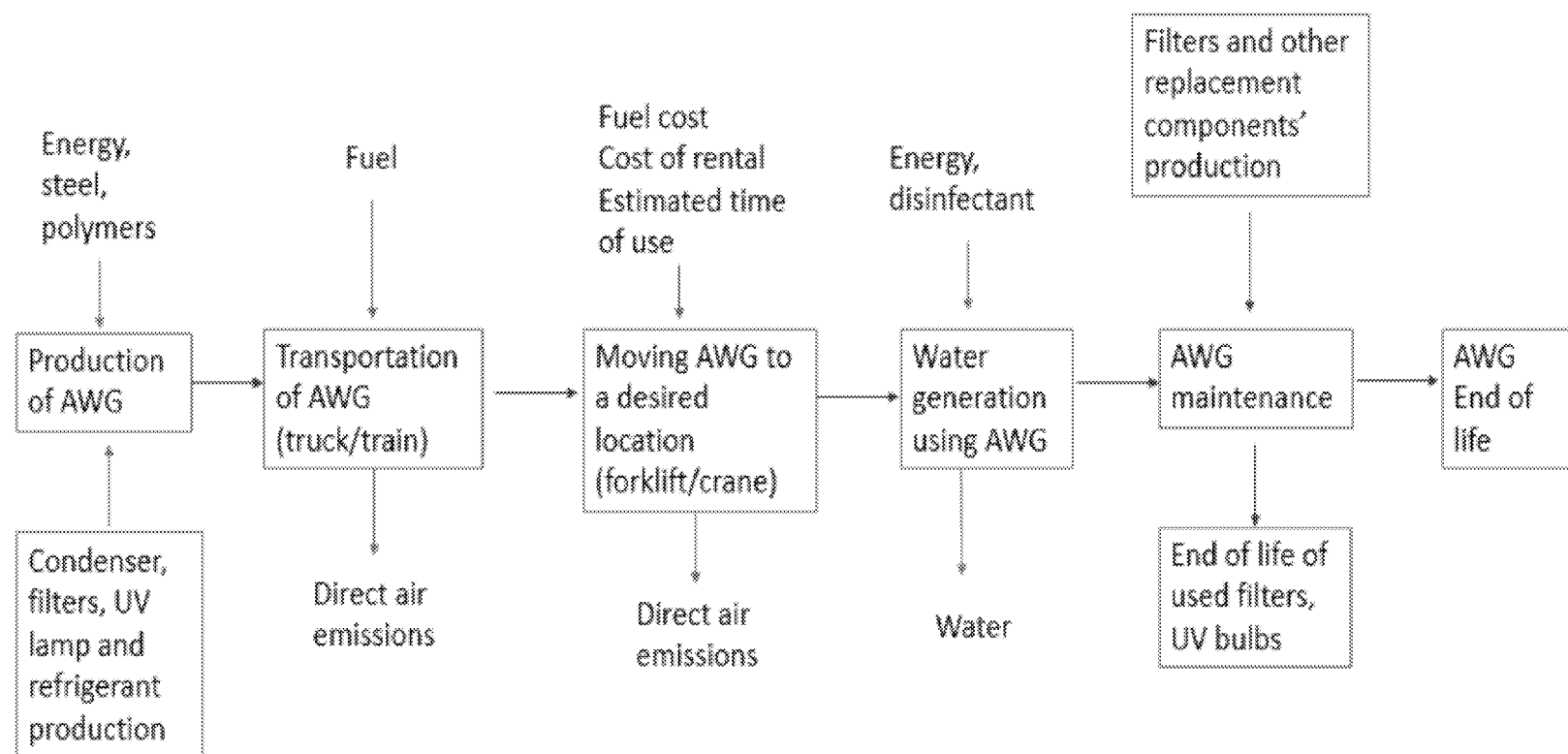
# AWG Systems Studied

Vendor	Scale	Weight (kg)	Volume Generated (L per day)	Electricity per volume produced (Wh/L)	Unit cost (\$)	Maintenance cost (\$)
Watergen	Large	2870	3000	350	115,000	7866
Watergen	Medium	800	400	330	55,000	2500
Watergen	Home/Office	50	25	300	1250	-
Ecolobue	Large	3800	3000	420	154,900 ( plus 4800 for external tank	3767
Ecolobue	Medium	1000	600	410	30,750	870
Ecolobue	Home/Office	50	30	300	799 (other 2 options cost 1299 and 1499)	-

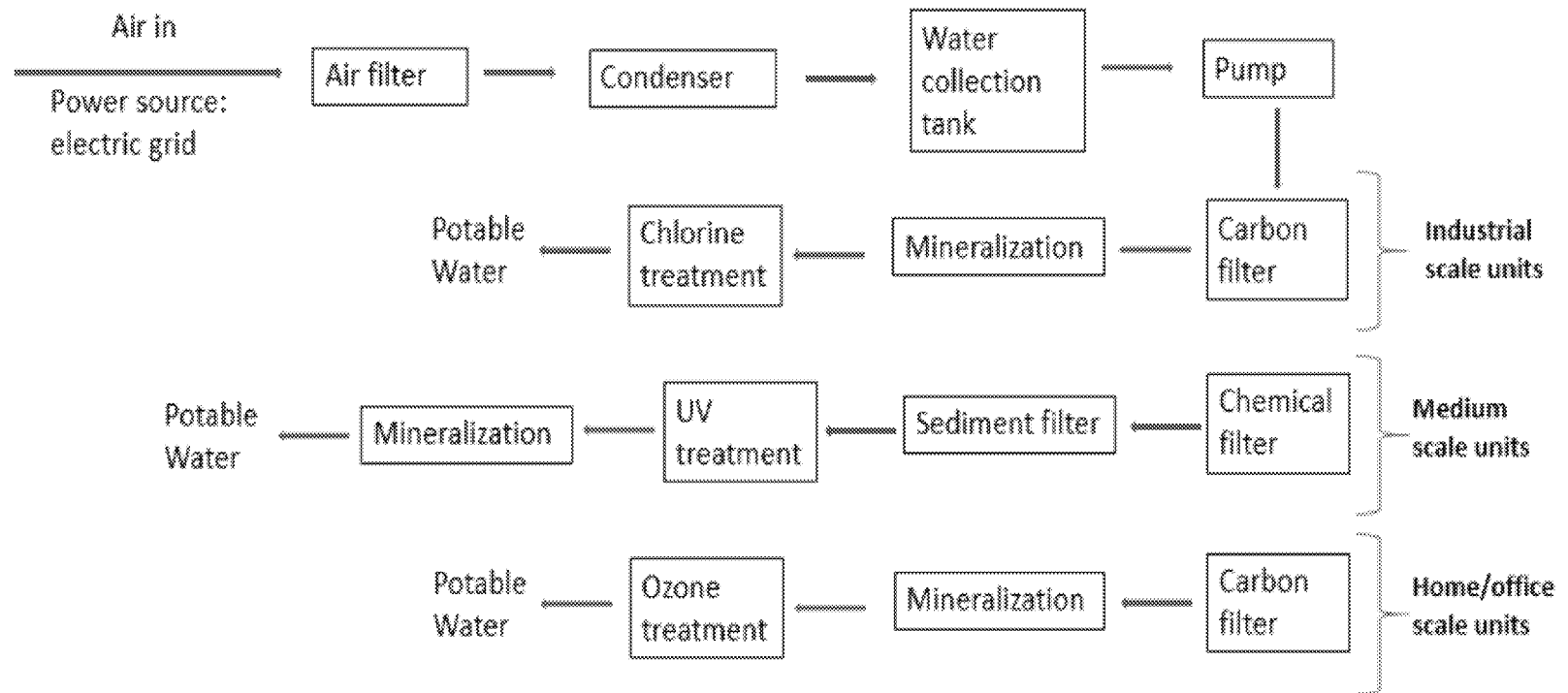
# Bottled Water Systems Studied

	Single-Serve Water Bottle	Multi-Serve Water Bottle
<b>Volume</b>	500 ml (16.9 oz)	18.9 L (5 gallons)
<b>Primary bottle material</b>	polyethylene terephthalate	polycarbonate
<b>Empty bottle weight (g)</b>	9.3	794 (1.75 lbs)
<b>Closure material</b>	Polypropylene	LDPE
<b>Closure weight (g)</b>	1.1	14.5
<b>Type of water</b>	Purified municipal water or spring water with ultrafiltration, ozone treatment, and UV.	
<b>Label material</b>	PP	n/a
<b>Label weight (g)</b>	0.6	n/a
<b>Multipack</b>	24-count	n/a
<b>Multipack packaging</b>	Shrink wrap (LDPE)	n/a
<b>Shrink wrap weight (g)</b>	31.5	n/a
<b>Type of reusable drinking container</b>	Not applicable	475 ml (16.1 oz) glass
<b>Recycling rate</b>	31.3%	100%
<b>Lifetime uses</b>	1	40

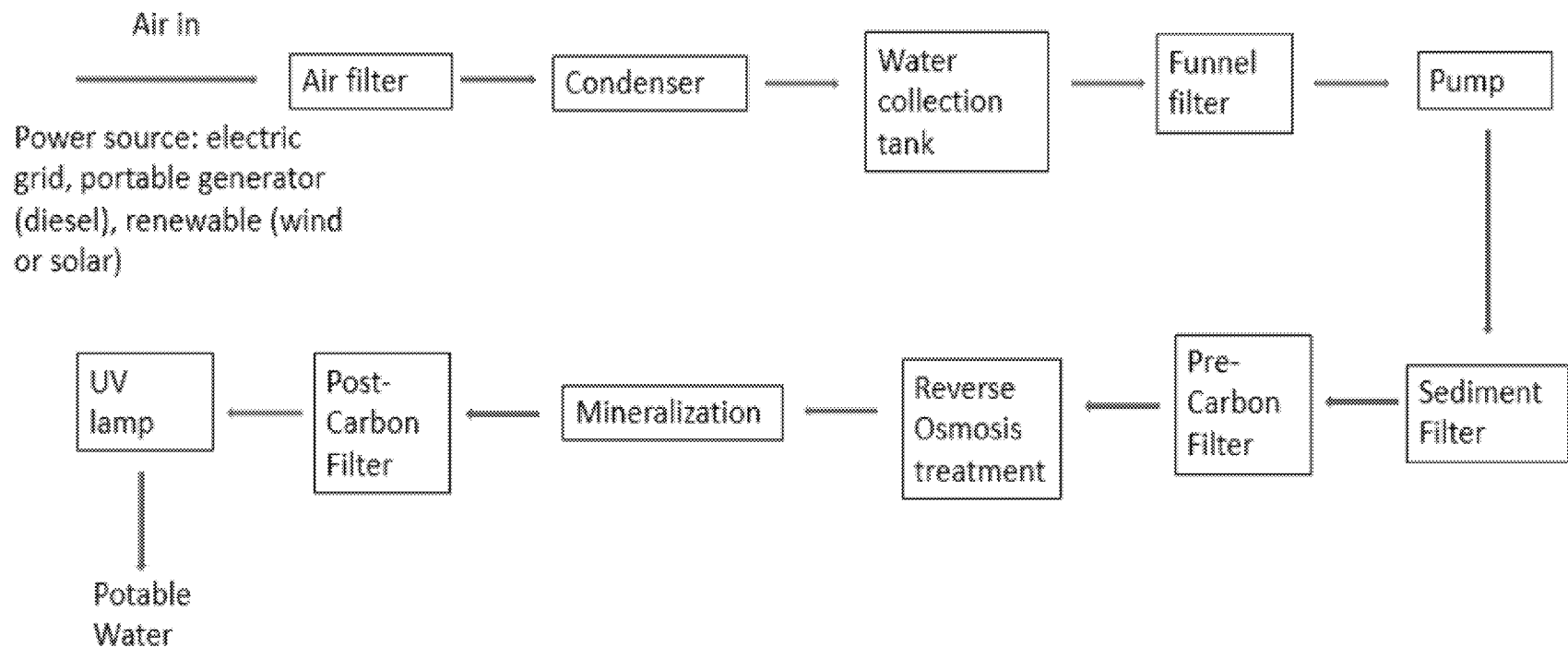
# System Boundary – AWG General



# System Boundary – Watergen



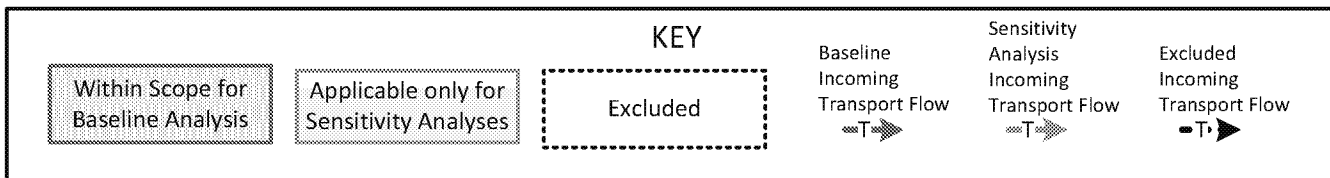
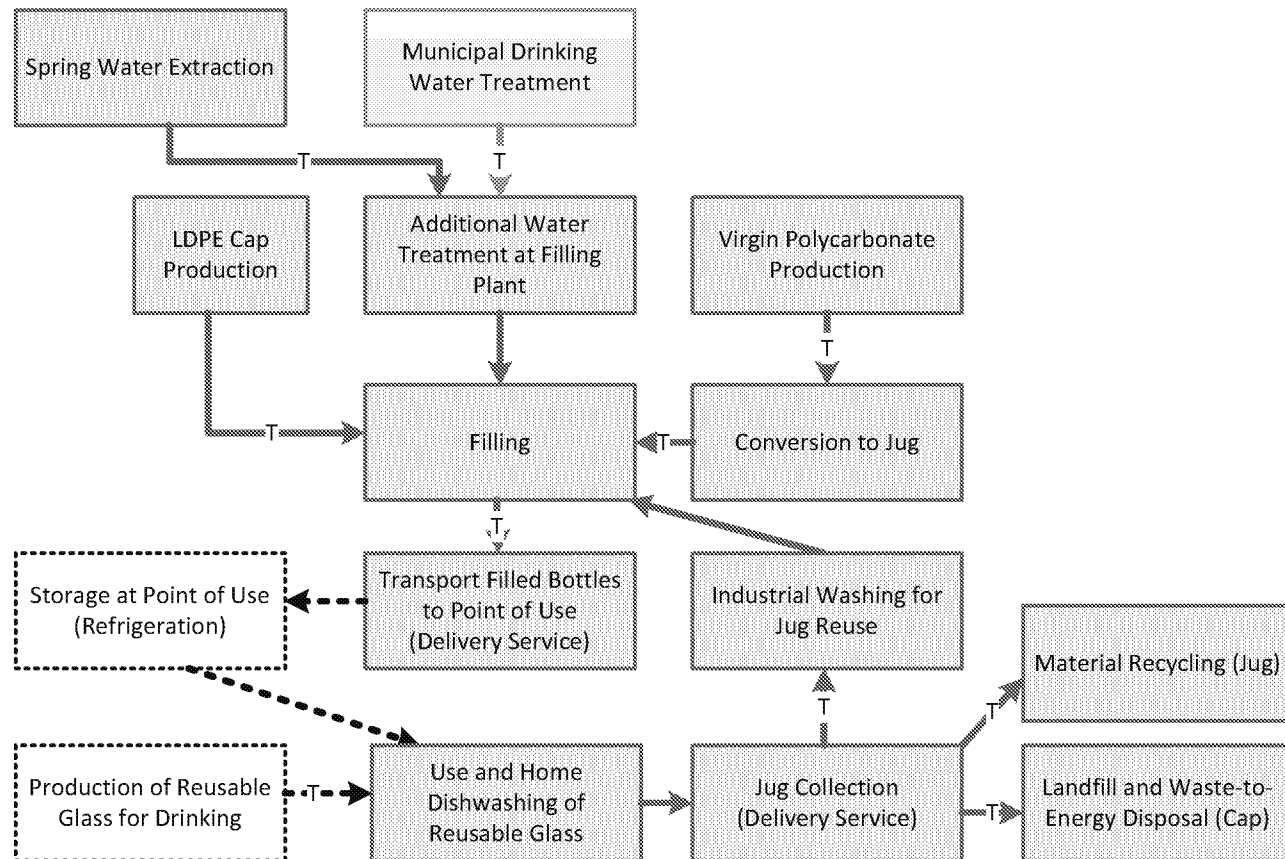
# System Boundary – Ecoloblue (All Scales)



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# System Boundary – Multi-Serve Jug



# Summary of AWG Scenarios

	WaterGen	EcoloBlue
<b>Scale</b>		
Industrial	✓	✓
Medium/light industrial	✓	✓
Home/office	✓	✓
<b>Grid mix</b>		
U.S. Average	✓	✓
FRCC	✓	✓
RFCW	✓	✓
<b>Water Production</b> (function of relative humidity and temperature)		
Minimum	✓	✓
Average	✓	✓
Maximum	✓	✓
<b>Reusable Container Washing Method</b>		
Dishwash	✓	✓
Handwash	✓	✓

# Summary of Bottled Water Scenarios

	Single-Serve Water Bottle	Multi-Serve Water Bottle
<b>Reusable Container Washing Method</b>		
Dishwash		✓
Handwash		✓
<b>Transport Distance</b>		
Maximum (125 mi)		✓
Average (75 mi)		✓
Minimum (25 mi)		✓
<b>Bottle Weight (lightweight)</b>		
Minimum (9.3g)	✓	
Maximum (10.9g)	✓	
<b>Bottle Recycled Content</b>		
0%	✓	
10%	✓	
<b>Recycling Allocation Method</b>		
Cut-off	✓	✓
System Expansion	✓	✓
<b>Bottled Water Source</b>		
Spring Water	✓	✓
Treated Municipal Water	✓	✓

# Baseline Assumptions

## Bottled Water

	Single-Serve Water Bottle	Multi-Serve Water Bottle
Reusable Container Washing Method	n/a	Dishwash
Transport Distance to Consumer (mi)	100	75*
Bottle Weight (g)	9.3	794
Bottle Recycled Content	0%	0%
Recycling Allocation Method	cut-off	cut-off
Bottled Water Source	Spring water	Spring water

*\*2 trips (filled jug for delivery, empty jug for return)*

## AWG

	Water-Gen	EcoloBlue
Scale	Large, medium, home/office	Large, medium, home/office
Grid mix	U.S. Average	U.S. Average
Water Production	Average	Average



# Scope of Impact Assessment

Category	Unit	Method	Description
Cumulative Energy Demand	MJ	Cumulative energy inventory	The cumulative energy demand indicator accounts for the total usage of non-renewable fuels (natural gas, petroleum, coal, and nuclear) and renewable fuels (such as biomass and hydro). Energy is tracked based on the heating value of the fuel utilized from point of extraction, with all energy values summed together and reported on a MJ basis.
Fossil Fuel Depletion	kg oil eq.	ReCiPe	Fossil fuel depletion captures the consumption of fossil fuels, primarily coal, natural gas, and crude oil. All fuels are normalized to kg oil equivalent (eq) based on the heating value of the fossil fuel and according to the ReCiPe impact assessment method.
Water Consumption	Liters H <sub>2</sub> O	Cumulative water consumption inventory	Freshwater withdrawals which are evaporated, incorporated into products and waste, transferred to different watersheds, or disposed into the sea after usage.
Solid Waste by Weight	kg	Cumulative solid waste inventory	The cumulative solid waste indicator sums up the total solid waste generated at each sub process of the product life cycle.
Acidification Potential	kg SO <sub>2</sub> eq	TRACI v2.1	Quantifies the acidifying effect of substances on their environment. Important emissions: SO <sub>2</sub> , NO <sub>x</sub> , NH <sub>3</sub> , HCl, HF, H <sub>2</sub> S.
Eutrophication Potential	kg N eq.	TRACI v2.1	Assesses impacts from excessive load of macro-nutrients to the environment. Important emissions: NH <sub>3</sub> , NO <sub>x</sub> , COD and BOD, N and P compounds.
Smog Formation Potential	kg O <sub>3</sub> eq.	TRACI v2.1	Determines the formation of reactive substances (e.g. tropospheric ozone) that cause harm to human health and vegetation. Important emissions: NO <sub>x</sub> , BTX, NMVOC, CH <sub>4</sub> , C <sub>2</sub> H <sub>6</sub> , C <sub>4</sub> H <sub>10</sub> , C <sub>3</sub> H <sub>8</sub> , C <sub>6</sub> H <sub>14</sub> , acetylene, Et-OH, formaldehyde.
Particulate Matter Formation Potential	kg PM <sub>2.5</sub> eq	TRACI v2.1	Determines the effect of particulate matter (e.g., PM 2.5 and PM <sub>10</sub> ) and pollutants which lead to respiratory impacts related to particulates (e.g., sulfur oxides and nitrogen oxides).

# Electrical Grid Fuel Mix Scenarios

eGRID subregion acronym	eGRID subregion name	Generation Resource Mix (percent)*										
		Coal	Oil	Gas	Other Fossil	Nuc- lear	Hydro	Biomass	Wind	Solar	Geo- thermal	Other unknown/ purchased fuel
<b>U.S. Average</b>		38.7	0.7	27.5	0.4	19.5	6.2	1.6	4.4	0.4	0.4	0.1
<b>FRCC</b>	FRCC All	16.0	1.2	66.6	0.0	12.8	0.1	2.4	0.0	0.1	0.0	0.7
<b>RFCW</b>	RFC West	67.8	0.6	11.4	0.7	20.8	0.7	0.6	2.4	0.1	0.0	0.1

\*percentages may not sum to 100 due to rounding



# Recycling Allocation (Jug and Bottle)

- Multiple approaches are available to partition (or allocate) impacts between the useful lives of a material:
  - **Cutoff:** Under this approach, distinct boundaries are drawn between the initial use of the material and subsequent uses of the material after recovery and recycling. All virgin material production burdens are assigned to the first use of the material, and the burdens assigned to the recycled system begin with recovery of the postconsumer material. For containers that are recycled at end of life, all of the burdens for material recovery, transport, separation and sorting, and reprocessing are assigned to the next system using the recycled material. Burdens associated with the final disposal of the product are assigned to the last useful life of the product.
  - **System Expansion:** the container system boundaries are expanded to include collection and reprocessing of postconsumer containers, as well as the net virgin material displacement or inputs required, based on the balance between the container system's closed-loop recycled content and closed-loop recycling rate. The types and quantities of materials that are displaced by the recovery and secondary processing of post-consumer container material determine the types and quantities of avoided environmental burdens.

# AWG Performance

Vendor	WaterGen			Ecoloblue		
	<i>Large</i>	<i>Medium</i>	<i>Home/Office</i>	<i>Large</i>	<i>Medium</i>	<i>Home/Office</i>
Maximum water produced (L/day)	4000	578	25	4781	962	30
Minimum water produced (L/day)	3000	38	15	193	50	20
Modeled value average water produced (L/day)	3000	400	25	3000	600	30
Reported Relative Humidity range (%)	60	20-70	60	30-80	30-80	0-60
Temperature range (°C)	26.7	15-40	26.7	0-55	0-55	25-100

# Data Sources

## ▪ AWG

- Data provided by WaterGen and Ecolobblue
- LCI databases: NREL's U.S. LCI, USEPA ORD, Ecoinvent, Franklin Associates' US Private LCI database

## ▪ Bottled Water/Jug

- **Municipal Drinking Water Treatment:** Cashman, S., Gaglione, A., Mosley, J., Weiss, L., Ashbolt, N., Hawkins, T., Cashdollar, J., Xue, X., Ma, C., and Arden, S. (2014). Environmental and cost life cycle assessment of disinfection options for municipal drinking water treatment. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/376
- **PET, LDPE, PP, HDPE Virgin Resin:** American Chemistry Council (ACC). (2011a). Cradle-to-Gate LCI of Nine Plastic Resins and Two Polyurethane Precursors. Franklin Associates, A Division of ERG. <http://plastics.americanchemistry.com/LifeCycle-Inventory-of-9-Plastics-Resins-and-4-Polyurethane-Precursors-Rpt-Only>
- **PET Recycled Resin:** Franklin Associates. (2011). Life Cycle Inventory of 100% Postconsumer HDPE and PET Recycled Resin from Postconsumer Containers and Packaging.
- **Plastic Conversion Processes:** ACC. (2011b). Life Cycle Inventory of Plastic Fabrication Processes: Injection Molding and Thermoforming. Franklin Associates, A Division of ERG. <https://plastics.americanchemistry.com/Education-Resources/Publications/LCI-of-Plastic-Fabrication-Processes-Injection-Molding-and-Thermoforming.pdf>.
- **Reusable Jug and Plastic Bottle Assumptions:** Oregon Department of Environmental Quality. (2009). Life Cycle Assessment of Drinking Water Systems: Bottle Water, Tap Water, and Home/Office Delivery Water. Franklin Associates, A Division of ERG, 09-LQ-104

# Contact

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